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Effectiveness of Splinting for Work-Related Carpal Tunnel Syndrome: A Three-Month Follow-up Study

by

Stella Tsz-Yee Li

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

Department of Occupational Therapy

Edmonton, Alberta

Spring, 1999

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Canada V5R 1M5

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The undersigned certified that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Effectiveness of Splinting for Work-Related Carpal Tunnel Syndrome: A Three-Month Follow-up Study submitted by Stella Tsz-Yee Li in partial fulfillment of the requirements for the degree of Master of Science.

Lili Liu, Ph.D.
Supervisor

Masako Miyazaki, M.Sc.

Sharon Warren, Ph.D.

Jan. 11, 1999
Date

ABSTRACT

The purpose of the study is to evaluate the effectiveness of splinting in relieving symptoms and improving functional status of clients with work-related carpal tunnel syndrome. The study used a quasi-experimental, time series, within-subject design. Twenty-two participants sampled from a hospital were examined and treated with the modified ulnar gutter wrist splint; they filled out self-administered questionnaires twice (1-2 weeks and immediately) before splinting and twice (2 weeks and 10-12 weeks) after splinting.

Participants showed significant improvement in symptom severity and functional status three months after splinting. Duration of symptoms, other medical conditions, work conditions, and non-compliant to splint wear seemed to be factors associated with the treatment outcome.

Future studies are recommended with a longer follow-up period, a larger number of participants, a randomized sample, and a control group for better generalization and increased validity of the results.

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CHAPTER 1

INTRODUCTION

With the increased use of computer keyboards and other work-related activities in today's society, carpal tunnel syndrome (CTS) has become the industrial epidemic syndrome of the decade, and its incidence is continually rising (Banta, 1994; Greer, Jenkins, & Roberts, 1992; Weiss, Sachar, Gendreau, & Providence, 1994; Workers' Compensation Board of Alberta, 1998).

In Canada, there is evidence of a marked increase in the number of newly reported work-related CTS in recent years, from 316 per annum in 1990 to 868 in 1997 in Alberta (WCB Alberta, 1998), and from 56 per annum in 1991 to 207 in 1996 in Nova Scotia (WCB Nova Scotia, 1997). The cost and compensation days for CTS claims have increased significantly as well. According to WCB of British Columbia (1998), each CTS claim in 1993 costs $8,327 in direct WCB payments, while in 1997 it costs $11,993 per claim. The overall costs for CTS claims in Alberta increased 2.9 times (from $1.3 million to $3.8 million) while the overall compensation days increased 1.7 times (from 18,013 days to 31,386 days) from 1990 to 1997 (WCB Alberta). CTS has become a public health issue that requires attention in prevention as well as early treatment programs.

CTS becomes a disabling condition when there is a loss of hand dexterity and strength. Thus, it is important to provide effective conservative treatment to settle the problem early and to prevent the need for invasive surgical treatment.

Splinting is one kind of conservative treatment used often for CTS. Studies have found that splinting is effective for CTS to relieve symptoms in a week (Dolhanty, 1986),

but recurrence of symptoms has been a concern (Weiss et al., 1994). Therefore, a longer follow-up period of splinting for a specific group of work-related CTS is needed. The purpose of this study was to evaluate the effectiveness of splinting in relieving symptoms and improving functional status of clients with work-related CTS.

Research Objectives

The primary objective was to determine whether clients with work-related CTS experienced a decrease in symptom severity and an improvement in functional status after splinting, as measured by the severity of symptom scale and the functional status scale in a three-month follow-up period.

The secondary objective was to describe the factors that seemed to be associated with the effectiveness of splinting for clients with work-related CTS.

Research Hypotheses

There were two null hypotheses for this study:

(1) Clients with work-related carpal tunnel syndrome will exhibit the same severity of symptoms as measured by the Symptom Severity Scale at 2 weeks and 10-12 weeks post-splinting.

(2) Clients with work-related carpal tunnel syndrome will exhibit no change in functional status as measured by the Functional Status Scale at 2 weeks and 10-12 weeks post-splinting.

CHAPTER 2

LITERATURE REVIEW

Carpal Tunnel Syndrome (CTS)

Carpal tunnel syndrome is the most common nerve entrapment syndrome and it involves median nerve compression within the carpal tunnel of the wrist (Burke, Burke, Stewart & Cambre, 1994; Dolhanty 1986; Greer et al., 1992). The carpal tunnel is formed by the carpal bones and ligaments. The median nerve and the finger flexor tendons run through this tunnel (Alberta Occupational Health and Safety, 1993; Greer et al., 1992). CTS is caused by increased pressure either externally to the wrist over the carpal tunnel or internally by swelling of the tissue within the carpal tunnel. As a result, early symptoms of numbness, pain, tingling may develop in areas innervated by the median nerve, that is: thenar muscles, volar aspect of thumb, index and long fingers, and radial side of ring finger. Symptoms are often most noticeable during sleeping hours. Later, clumsiness and weakness of the hand may occur. Individuals may eventually have difficulty grasping and holding objects. They may drop things. Finally, there may be thenar atrophy with permanent damage of the nerve. The result is a disabling condition of the hand(s) (Alberta Occupational Health and Safety, 1993; Courts, 1995; Dolhanty; 1986). CTS most commonly affects middle-aged female (de Krom et al., 1992; Katz, 1994). Studies show that 16% to 64% of individuals with CTS have bilateral involvement (Banta, 1994; Burke et al., 1994; Courts, 1995; Dolhanty, 1986; Kaplan, Glickel & Eaton, 1990; Kruger, Kraft, Deitz, Ameis & Polissar, 1991; Stanek & Pransky, 1996; Weiss et al., 1994). CTS can be diagnosed clinically by the subjective report from

clients, Phalen's test, Tinel test, or nerve conduction test. The last test is not used often due to its cost and the discomfort it causes. CTS may be related to occupation, trauma to the wrist, diabetes, pregnancy, or other medical conditions (Alberta Occupational Health and Safety, 1993; Cimmino, Parisi, Moggiana, & Accardo, 1996; Courts, 1995; Dolhanty, 1986; Greer et al., 1992; Perez-Ruiz et al., 1995; Pfalzer, & McPhee, 1995).

Work-related CTS

Researchers find that the incidence of work-related CTS has increased in recent years (Greer et al., 1992, Louis, Calkins & Harris, 1996). This results in costs to the employers and workers compensation insurance companies, in addition to the disabling condition of the employees. Occupations that require repetitive motion of the wrist, exertion on the wrist in extreme extension or flexion, vibration of the wrist, or working in cold temperatures present risks for CTS. Individuals at risk include computer operators, typists, assembly line workers, butchers, packers, hairdressers, dental hygienists, dentists, carpenters, construction workers, and musicians (Alberta Occupational Health and Safety, 1993; Greer et al., 1992; Wolens, 1996).

Treatment for CTS

There are many treatment methods for CTS. These include conservative treatments such as splinting, anti-inflammatory medications, steroid injections, vitamin B6, activity modification, ergonomics, exercise, and surgical treatment which is more invasive (Banta, 1994; Bracker & Ralph, 1995; Kaplan et al., 1990; Sailer, 1996; Weiss et al., 1994). Occupational therapists are trained to fabricate splints. It has been found that

CTS accounts for approximately 65% of the splints fabricated for clients in occupational therapy (Kruger, Veer, & Nicholls, 1992).

Rationale for Splinting for CTS

The rationale for splinting as a conservative treatment for CTS is that the splint helps to relieve pressure on the carpal tunnel, thereby reducing the symptoms of pain, numbness, and tingling. It has been demonstrated that clients with CTS have elevated resting intracanal pressure, and that wrist extension and flexion result in three to six times more pressure in the wrist than if it were placed in a neutral position (Kruger et al., 1991; Rempel, Manojlovic, Levinsohn, Bloom, & Gordon, 1994). Splinting for CTS at a neutral wrist angle has been shown to provide superior symptom relief compared with other angles (Burke et al., 1994; Kruger et al., 1991; Luchetti et al., 1994), while splinting with about 5 degrees of wrist flexion has also been reported to be effective (Dolhanty, 1986). Immobilization of the wrist in neutral maximizes available carpal tunnel space, minimizes compression to the median nerve, and thus provides symptom relief. Splinting remains a popular initial treatment and, in some cases, may be the only necessary treatment.

Evidence of the Effectiveness of Splinting for CTS

Studies show that splinting is effective for early mild CTS in initial symptoms relief (Dolhanty, 1986; Weiss et al., 1994), but the long term effectiveness is less certain (Weiss et al.). Dolhanty (1986) finds that splinting for one week significantly reduced the symptoms of numbness, pain, and tingling associated with CTS in six subjects, with six others put in a control group. However, Dolhanty (1986) recommends that a longer

follow-up period and more detailed measurements of the subjects' symptoms and severity are needed for further validation of the results.

In studies with 2 to 17 months follow-up period, success rates of 13% to 67% have been found among subjects treated with splints (Banta, 1994; Burke et al., 1994; Kruger et al., 1991; Weiss et al., 1994). Weiss et al. (1994) performed a study using 57 subjects (76 hands) with CTS. Splinting and steroid injections were provided. Only 13% of the subjects (10 hands) reported no symptoms at the final evaluation after a 11-month follow-up period. Kruger et al. (1991) demonstrated symptom relief in 67% of the 105 subjects with CTS, using a modified ulnar gutter wrist splint during a 17-month follow-up period. As a yes/no question is used in both studies, subjects with partial symptom relief may have been missed.

Results of a 6-month follow-up study on splinting and anti-inflammatory medications for 23 hands of 18 subjects with CTS show that only 17% of the subjects (4 hands) reported total relief of the symptoms (Banta, 1994). However, the duration of clinical symptoms before splinting varied among subjects from 2 months to 10 years. Subjects with longer duration of symptoms were likely to be less responsive to splinting (Dolhanty, 1986; Kruger et al., 1991).

Burke et al. (1994) compared the subjective ratings of symptom relief between 2-week and 2-month splinting in 71 wrists with CTS. Twenty-four percent of the subjects reported symptom improvement, 59% reported no change and 17% reported worsening of symptoms. It has been suggested that symptoms may not often improve between 2-week and 2-month of splint use. Recurrence rates of 34% to 90% have been reported after the initial symptom-free period (Weiss et al., 1994), possibly related to compliance with splint wear.

Other than general CTS, Courts (1995) has performed a study on the use of splints for CTS in pregnancy, showing that splinting helps to decrease the uncomfortable symptoms of CTS during pregnancy. However, no studies have been done specifically on splinting the clients with work-related CTS. Differences are expected between general CTS and work-related CTS. Some CTS relates to medical conditions such as arthritis and hypothyroidism. There may be structural changes within the carpal tunnel that are unlikely to respond to treatment like splinting, or the symptoms may resolve once the medical condition is under control.

Predictive Factors in Splinting for CTS

Some predictive factors are suggested to be correlated with the effectiveness of splinting for CTS in symptom relief. Splinting is suggested to be most effective if applied within three months of symptom onset (Kruger et al., 1991). Kaplan et al. (1990) evaluated 331 hands in 229 CTS subjects who were treated with splinting and medication. Some factors have been identified as important in predicting failure in responding to conservative treatment: age over 50 years, symptom onset over 10 months, constant paraesthesiae, stenosing flexor tenosynovitis, a positive Phalen's test within 30 seconds, and thenar atrophy. Stahl and Yarnitsky (1996) present similar criteria to predict success and failure of conservative therapy with corticosteroid injection and splinting in a study involving 48 CTS patients (60 hands). However, symptom duration and paraesthesia have been mentioned in predicting success but not in predicting failure of conservative therapy. Myles and Macsweeney (1995) suggest that the most reliable prognostic factor is the duration of symptoms. Longer symptom onset is associated with worse prognosis. Weiss et al. (1994) studied splinting and steroid injection in 76 hands in

57 subjects with CTS. Women and individuals under 40 years of age were found to have a slower rate of symptom resolution when treated conservatively. Thus, duration of symptoms, age, gender, constant paraesthesiae, positive Phalen's test, and thenar atrophy are the possible factors that affect the results of splinting for symptom relief (Kaplan et al., 1990; Myles & Macsweeney, 1995; Stahl & Yarnitsky, 1996; Weiss et al., 1994).

Compliance with Splint Wear

Obviously, compliance with splint wear is very important for optimal treatment results and for evaluation of the effectiveness of splinting for the affected hand. Sailer (1996) has written a comprehensive splinting regime for CTS to match the splint to the clients' occupation, lifestyle, and tolerance so as to increase client compliance with splint wear.

Rationale for the Study

Some studies demonstrate that splinting for CTS is effective for short term symptom relief while others suggest a relatively low success rate. The long term effectiveness of splinting for CTS symptom relief is less certain, and the improvement in functional status of the subjects are not known in previous studies. Therefore, a study is required with a longer follow-up period on splinting for CTS using an instrument to evaluate the severity of symptoms and the functional status of subjects. Although the incidence of work-related CTS continues to rise, no studies have been done on the effectiveness of splinting for this condition. Thus, a study to evaluate splinting for work-related CTS will be valuable in adding to the existing knowledge on splinting and CTS. Recurrence of symptoms has also been observed in some cases. This may relate to the

non-compliance of splint wear. Therefore, the splint must match the clients' needs to enhance compliance.

In view of the above reasons, a study on the effectiveness of splinting for work-related CTS in a three-month follow-up period was performed, using the Symptom Severity Scale and the Functional Status Scale as measuring instruments. A lightweight modified ulnar gutter wrist splint was used in the study because it fulfilled most of the requirements in matching the clients' needs, thus enhancing compliance. Factors that might affect the result of splinting were considered.

CHAPTER 3

METHODOLOGY

Sample

One sample of individuals with work-related CTS was selected as a sample of convenience through the Langley Memorial Hospital (LMH) in Langley, British Columbia. All participants were clients referred by physicians for splinting to the Occupational Therapy (OT) Department in LMH. Verbal support for the study was obtained from the hand surgeons and family physicians in Langley. Clients were included if they were of either gender, 18 years or older, diagnosed by a physician as having CTS, and having work-related CTS as reported by themselves. The investigator performed Phalen's test and Tinel test with the clients to confirm the diagnosis of CTS before splinting. Clients with constant paraesthesiae and thenar atrophy of the hands were excluded in order to meet the criteria of mild CTS. Participants should experience characteristic CTS symptoms such as numbness, tingling, pain, and weakness of the affected hand and wrist, with or without confirmation of nerve conduction tests. The duration of symptoms was not limited. If a participant was splinted bilaterally, both hands were used for the study.

The use of a sample of convenience allowed the investigator to complete the study within a reasonable time frame. Characteristics of the study participants were compared to the general population with CTS.

Initially, a sample size of 28 was set with $\alpha = .05$ and $\beta = .10$ to allow for a high power of .90. As the number of referrals for CTS splinting to the OT Department at LMH was much lower than the previous year, β was changed to .20 to allow for a

reasonably high power of .80. The sample size became 22 which provided a power of .80 at $\alpha = .05$. (see Appendix A). An additional 3 participants were included to accommodate for a potential 15% drop-out rate. Sampling continued until a total of 25 participants was obtained. This was achieved in 14 months during the September, 1997 to November, 1998 period.

Study Design

This study used quasi-experimental, time series, within-subject design to administer specific outcome measures at periodic intervals before and after splinting in the same group, for a three-month follow-up period. The intervals for measurement were as follows:

O	O	X	O	O
1-2 weeks before	immediately before	splinting	2 weeks after	10-12 weeks after

There were two pre-measures and two post-measures. An interval of 1-2 weeks before splinting was selected as the first pre-measure, because the waiting period for OT out-patient splinting appointments was usually 1-2 weeks. The two pre-measures allowed the investigator to detect whether a trend towards symptom relief and functional improvement had already begun before the splint was applied (that is, symptoms and function were getting better on their own). Regarding the intervals chosen for post-measure, 2 weeks was for detecting short term results (Dolhanty in 1986 has demonstrated the effect of splinting after one week), while 10-12 weeks was for detecting long term results of splinting (in previous studies by Banta in 1994, Burke et al. in 1994,

Kruger et al. in 1991, and Weiss et al. in 1994, two to seventeen months were picked for long term follow-up). Because of the multiple outcome measures in this design, we were more confident in the baseline and outcome data than in the one group pre-test post-test design.

A control group, as incorporated by Dolhanty in a short term study in 1986, was not used in this long term follow-up study, because hospital policy did not allow clients to be denied a potentially useful treatment like splinting.

Historical events (such as other medical conditions) were identified during the initial interview with the participants so that the potential effects of these events on the outcome measure could be examined.

Data Collection

Data were collected at the OT Department of LMH using self-administered questionnaires during three scheduled visits by the participants.

All eligible clients were mailed an introductory letter (Appendix B), a consent form (Appendix C), and a first questionnaire. Following this, the receptionist from the OT Department phoned the clients to invite them to participate in the study and schedule them for an occupational therapy appointment. After verbal consent, the participants were requested to fill out the first questionnaire at home 1 to 2 weeks before their occupational therapy appointment. Because of a postal strike, some participants did not receive the first questionnaire and were contacted directly by telephone instead. On the day of application of the CTS splint(s), the investigator described the study, explained and had the participants signed the consent form, answered questions, administered the Edinburgh Handedness Inventory (Bryden, 1977; Oldfield, 1971; Raczkowski & Kalat,

1974, Appendix D) to determine handedness, and had the participants complete the second questionnaire. Those who did not receive the first questionnaire by mail were requested to fill out the first questionnaire retrospectively with the second questionnaire. Phalen's test, Tinel test, and the Jamar power grip strength test were performed with all participants during every visit. Two weeks after splinting, participants returned for follow-up occupational therapy, and to complete the third questionnaire. The investigator contacted the participants by phone 4 to 8 weeks after splinting to monitor compliance with splint wear if CTS symptoms still existed. The participants were reminded to fill out the splint wearing schedule record cards, and appointments were made for them to return 10 to 12 weeks after splinting to fill out the fourth questionnaire. Some participants did not show up for the last appointment. Because of that, some data for the Phalen's test, Tinel test, and the Jamar power grip strength test were lost. These participants were all contacted by phone. With verbal agreement, data for the fourth questionnaire were collected either by home visit, by mail, or by telephone.

To help ensure confidentiality, the names of the participants were replaced by codes as soon as the questionnaires were completed. The collected data was kept in a secure place in the Hospital, and a copy of the raw data was kept at the University of Alberta .

The participants could complete the questionnaire at any time of the day, regardless of whether they were wearing the splint, because the questionnaire had already addressed symptoms at different times of a day, and participants had been given clear splint wearing instructions and a self-recorded wearing schedule.

The principal investigator was also the therapist in this study. She was responsible for preparing and mailing of introductory letters, consent forms, and questionnaires;

conducting the introductory sessions; monitoring the completion of questionnaires; maintaining telephone contact; keeping confidentiality of data collected; and making the splints and providing splinting information.

Variables

The independent variable was: splinting. The modified ulnar gutter wrist splint was used in this study.

The dependent variables in this study were: (1) symptom severity, and (2) functional status of the client with CTS. These variables were measured using the Symptom Severity Scale and the Functional Status Scale in the questionnaires.

The intervening variables might be: occupation, gender, age, duration of symptoms, hand(s) splinted, handedness or comorbid conditions. The confounding variables might be: history of other treatments such as anti-inflammatory medications or steroid injections. These were recorded as the background information in the questionnaires.

Splinting and Treatment Protocol

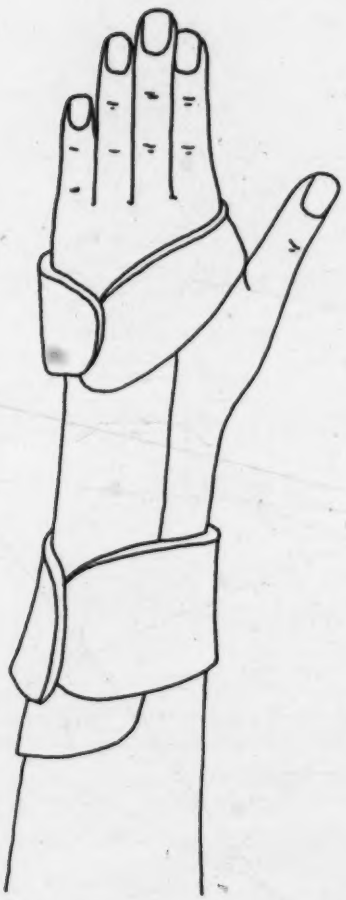
A modified ulnar gutter wrist splint made from low temperature thermoplastic materials was used in this study (See Figures 1a, 1b, and 1c for illustrations of the splint). This splint had been used in a study conducted to assess the efficacy of CTS splinting (Kruger et al., 1991), and its construction was described (Kruger et al., 1992). Compared to the traditional volar-based splint, this ulnar gutter wrist splint has the advantages of minimizing sensory occlusion and allowing greater ease of forearm rotation, while

maintaining the wrist in a neutral position. Material cost was reduced, and the splint was lightweight and easy to don and remove (Fess & Philips, 1987; Kruger et al., 1992).

The splint was molded with the wrist placed in a neutral position, which had been shown to be the optimal angle for CTS splinting (Burke et al., 1994; Kruger et al., 1991).

The treatment protocol was as follows. The occupational therapist explained to the participants what CTS was, the purpose of the splint, when to wear it, how to care of it, and the precautions. The participants should wear the splint at night and/or during the day when performing activities that required repetitive or extreme wrist motion (Dolhanty 1986; Kruger et al., 1992; Sailer, 1996). They were given record cards to record their splint wearing schedule. If worn during the day, the splint should be removed for wrist exercises at least twice daily to prevent stiffness (Sailer, 1996). Both verbal and written splinting information were provided. The participants were asked to report to the therapist immediately if there were any concerns regarding CTS splinting. (See Appendix E: Splinting Information Sheet, and Appendix F: Splint Wearing Schedule Record Card).

Figure 1a: **Modified Ulnar Gutter Wrist Splint for the Treatment of Carpal Tunnel Syndrome**



Dorsal View

Splint design obtained from Kruger, Veer & Nicholls, 1992.

Figure 1b: **Modified Ulnar Gutter Wrist Splint**

for the Treatment of Carpal Tunnel Syndrome

Volar View

Splint design obtained from Kruger, Veer & Nicholls, 1992.

Figure 1c: **Modified Ulnar Gutter Wrist Splint for the Treatment of Carpal Tunnel Syndrome**

Side View

Splint design obtained from Kruger, Veer & Nicholls, 1992.

Instrument: Self-Administered CTS Questionnaire

A self-administered questionnaire (Appendix G) was used to measure the dependent variables: symptom severity, and functional status of the subjects before and after splinting. This questionnaire was developed by Levine et al. in 1993 for the assessment of symptom severity and functional status in patients with carpal tunnel syndrome, and had been used for several clinical and methodological projects (Bessette et al., 1998; Bessette, Keller, Lew, et al., 1997; Bessette, Keller, Liang, et al., 1997; Katz et al., 1997; Katz et al., 1998; Pransky, Feuerstein, Himmelstein, Katz, & Vickers-Lahti, 1997). A background information section was added to the original questionnaire to identify possible intervening and confounding variables. There were two sets of background information: the first set was designed for the first questionnaire, while the second set was for the second to the fourth questionnaires.

The questionnaire included an 11-item Symptom Severity Scale, and an 8-item Functional Status Scale, both rated on 5-point score (5 indicates the worst and 1 indicates the best). Psychometric properties of the questionnaire have been established (Levine et al., 1993). Content validity has been examined using consultation with a panel of experts, pilot testing, followed by a revision of the questionnaire. Six critical domains have been identified for the evaluation of CTS: pain, paresthesia, numbness, weakness, nocturnal symptoms, and overall functional status. The reproducibility, internal consistency, construct validity, and responsiveness of the scales to clinical change have been investigated in a clinical study, with 31 to 67 patients being evaluated pre- and post-operatively (Levine et al.). The scales are found to have high test-retest reliability (Pearson's $r=.91$ and .93 for severity of symptoms and functional status, respectively), and high internal consistency (Cronbach's $\alpha=.89$ and .91 for severity of symptoms and

functional status, respectively). Construct validity is shown by the high correlation between functional status scores and symptom severity scores, and the expected positive but moderate or weak correlation with traditional clinical measures of CTS (i.e. grip strength, pinch strength, two-point discrimination, Semmes-Weinstein monofilament testing, and median nerve sensory conduction velocity). In a 14-month post-operative follow-up evaluation, the scales are found to be responsive to clinical change (mean symptom severity score improved from 3.4 to 1.9, and mean functional status score improved from 3 to 2).

Data Analysis

The Statistical Package for the Social Science Release 8.0 (SPSS Inc., 1997) was used to analyze the data. All 25 participants (33 hands) were contacted at 2 weeks, with 3 participants (4 hands) lost to long term follow-up due to surgery, death, and misdiagnosis. For the participant who was misdiagnosed, the physician informed her after her first visit to Occupational Therapy that she did not have CTS but tendinitis, and so she did not return for follow-up. Participants with bilateral CTS could not distinguish symptoms between the two hands. Therefore, only one set of data was collected from each of them. Hence, 22 sets of data from 22 participants (29 hands) were analyzed. There were no missing data.

There were three categories of data for statistical analysis:

(1) Symptom severity: from 1 to 5 points, 11 questions (dependent variable);

(2) Functional status: from 1 to 5 points, 8 activities (dependent variable);

(3) Background information: gender, hand(s) splinted, handedness, age, duration of symptoms, occupation, comorbid conditions, and history of other treatments for CTS (possible intervening and confounding variables).

Descriptive statistics were used for all three categories. Symptom severity and functional status were treated as interval data so that means, standard deviations, and 95% confidence intervals were used to describe the results. Percentage and number were used to summarize nominal data of gender, hand(s) splinted, handedness, occupation, comorbid conditions, and history of other treatments. Means, standard deviations, and range were used to summarize the ratio data of age and duration of symptoms. Occupations were categorized according to the National Occupational Classification (NOC) from the Employment and Immigration Canada (1993).

Inferential statistics were employed to analyze the symptom severity and functional status. As the two dependent variables were measured repeatedly before and after treatment, and the data were of interval level, results were analyzed by Repeated Measures Analysis of Variance (Norman & Streiner, 1986). Post hoc, Tukey's Honestly Significant Difference (HSD) Test was used to test each of the possible comparisons. It is one of the simplest and most conservative multiple comparison procedures that offers generous protection against Type I error using a family-based error rate, which was set at 5% in this study (Glass & Hopkins, 1996; Klockars & Sax, 1986; Portney & Watkins, 1993).

Observations from the the Phalen's test, Tinel test, power grip strength test, and the open-ended questions were reported. For example: one participant had a significant change in activity pattern because she started to use ergonomic equipment at work. The characteristics of participants with positive and negative outcomes from splinting were

described (using the background information) so as to get an impression of the important factors associated with positive outcome that could be tested in a larger study. Positive outcome was defined as improvement in symptom severity or functional status as indicated by a decrease in the mean score difference in the 5-point scale (e.g. from 2.5 to 1.8). Significant improvement were indicated by the Tukey's HSD. i.e. a positive mean score difference of larger than .40 for symptoms and .39 for function before and after splinting. Negative outcome was defined as deterioration in functional status as indicated by a increase in the mean score difference in the 5-point scale (e.g. from 2.5 to 3.0). Significant deterioration was indicated by the Tukey's HSD. i.e. a negative mean score difference of smaller than -.40 for symptoms and -.39 for function before and after splinting.

The level of significance was set at an α level of .05. This α level was used for a high probability of detecting a difference if one existed. That meant, if splinting did make a difference, we did not want to miss detecting it. The power of this study ($1-\beta$) was reasonably high as a β of .20 was chosen for an 80% chance of detecting an effect.

Ethical Considerations

This study was non-invasive and inexpensive because splinting was the ordinary treatment by occupational therapist for clients with CTS. There was minimal risk and harm to the participants. They were required only to put in the effort and the time in filling out the questionnaires. The precautions in wearing a splint (e.g. chances of getting pressure points, joint stiffness if not removing splint for exercise) were explained using verbal and written splinting instructions, as was routinely done. The merit of this study

was better treatment for CTS. The participants paid 15% less for their splints upon consent to participate in the study.

Ethics approval was granted by the Research Ethics Committee of Langley Memorial Hospital (See Appendix H: Ethics Approval Letter). This met the ethical requirements of the University of Alberta. A consent form was signed by the participants before they participated in this study. The investigator explained to all participants about voluntary participation, the right to withdraw without consequence, and confidentiality of the information obtained. Their names would not be released to anyone other than the investigators, and would be identified only as code numbers.

CHAPTER 4

RESULTS

Of the 22 participants (29 hands) who were treated with CTS splints for three months, 15 (68%) had significant improvement, 2 (9%) showed non-significant improvement, and 5 (23%) did not show improvement in symptoms. Eight participants (36%) had significant improvement, 8 (36%) showed non-significant improvement, and 6 (27%) did not show improvement in function. One participant who did not show improvement had unchanged symptoms, 4 had a deterioration of not more than .64 in symptom severity, 4 had unchanged function, and 2 had a deterioration of not more than .37 in functional status on the 5-point scale.

Demographic Characteristics

Table 1 describes the demographic characteristics of the participants. The female/male ratio was 64% to 36%. All were right-handed. Forty-six percent had only their right hand splinted, 23% had only their left hand splinted, and 32% were splinted bilaterally. There was a wide age range of 18 to 73 years, and a duration of symptoms from 1 to 260 weeks. Because of two extreme values of 104 weeks (n = 1) and 260 weeks (n = 2), the standard deviation of duration of symptoms was high (SD = 74.16). Participants were involved in five groups of occupations according to the National Occupational Classification (Employment and Immigration Canada, 1993) (Table 2). All of these occupations require repetitive or forceful hand movements or both. Other medical conditions and treatments for CTS received by the participants are presented in Tables 3 and 4.

Table 1

Demographic Characteristics

	N = 22	
	%	n
Gender		
Female	63.6	14
Male	36.4	8
Hand(s) splinted		
Right	45.5	10
Left	22.7	5
Bilateral	31.8	7
Handedness		
Right	100	22
Left	0	0

		N = 22	
	Range	M	SD
Age (years)	18 - 73	44.70	15.00
Duration of symptoms (weeks)	1 - 260	41.82	74.16

Table 2

Occupation

N = 22	
Description (NOC Code)	n
Clerical Occupations (124[a], 141[b], 142[c], 143[d], 144[e])	9
Graphic Arts Occupations (522[f])	1
Sales and Service Occupations (622[g], 623[h], 642[i], 647[j], 661[k])	8
Trades, Transport and Equipment Operators, and Related Occupations (724[m], 743[n], 762[p])	3
Electronics Assemblers (948)	1

Note. NOC = National Occupational Classification.

[a]124: Secretaries: Data Entry 5-6 hours/day, Switchboard 1-1 ½ hour/day (n = 1)
[b]141: Clerical Occupations, General Office Skills: 6-7 hours/day computer keyboard (n = 1)
[c]142: Office Equipment Operators: Typing 6-10 hours/day: (n = 3)
[d]143: Finance and Insurance Clerks: Computer Use, Writing, Telephone Use (n = 3)
[e]144: Administrative Support Clerks: Data Entry, Writing (n = 1)
[f]522: Graphic Arts Occupations: Picture Framing and Industrial Arts Teaching (n = 1)
[g]621: Retail Sales Supervisors: Cashier, Stocking, Paperwork (n = 1)
[h]622: Technical Sales Specialists and Wholesale Trade (n = 2)
[i]623: Real Estate Sales Occupations: Computer and Telephone Use (n = 1)
[j]647: Child Care and Home Support Workers (n = 3)
[k]661: Cashiers (n = 1)
[m]724: Electricians: Use of Hand Tools, Electrical Cables Pulling 8 hours/day (n = 1)
[n]743: Other Transport Equipment Operators and Related Workers: Truck Driving, Oil Pulling and Data Entry (n = 1)
[p]762: Construction Laborers: Panel Building (n = 1)

Table 3

Other Medical Conditions

N = 22

Condition	n
Tendinitis	3
Rheumatoid Arthritis	1
Diabetes & Fibromyalgia	1
Diabetes, Neuropathy, Angina & Anxiety	1
Epilepsy, Colitis & Asthma	1
Plantar Fasciitis	1
Other (Colitis, Cancer, Eczema)	3
None	11

Table 4

History of Other Treatments (for Carpal Tunnel Syndrome)

N = 22

Treatment	n
Anti-inflammatory	1
Anti-inflammatory & Physiotherapy	2
Anti-inflammatory & Analgesics	1
Analgesics	4
Cortisone injection	1
Cortisone injection and Analgesics	1
Tensor bandage	1
None	11

Symptom Severity and Functional Status

Table 5 summarizes the mean symptom severity scores and functional status scores, and their standard deviations and 95% confidence intervals at four points of measure.

The repeated measures analysis of variance for symptom severity and functional status are presented in Table 6. There was a statistically significant decrease in symptom severity after splinting ($F = 19.03$, $p = .0000$, $df = 3$). Overall, the improvement in functional status after splinting was also statistically significant ($F = 7.02$, $p = .0004$, $df = 3$). In Table 7, post hoc Tukey's HSD test showed that decrease in symptom severity were statistically significant from immediately before splinting to 2 weeks after splinting (mean score difference = .59), and from immediately before splinting to 10-12 weeks after splinting (mean score difference = .86). There was a statistically significant improvement of functional status from immediately before splinting to 10-12 weeks after splinting (mean score difference = .53). The mean score difference of functional status from immediately before splinting to 2 weeks after splinting was not statistically significant (mean score difference = .31). The changes in symptom severity and functional status from 1-2 weeks before splinting and immediately before splinting were both not statistically significant (mean score difference = .10 and .06).

Table 5

Mean Symptom Severity Scores and Functional Status Scores (N = 22)

	Time (Measure)			
Dependent Variable	1-2 weeks pre-splinting	Immediately pre-splinting	2 weeks post-splinting	10-12 weeks post-splinting
Symptom Severity				
M	2.60	2.50	1.91	1.64
SD	.76	.79	.58	.50
95% CI				
Lower	2.26	2.15	1.65	1.41
Upper	2.94	2.85	2.17	1.86
Functional Status				
M	2.17	2.11	1.81	1.58
SD	.90	.83	.76	.62
95% CI				
Lower	1.77	1.75	1.47	1.31
Upper	2.57	2.48	2.14	1.85

Note. Maximum score = 5, Minimum score = 1. A lower score indicates better symptoms or functional status.

Table 6

Repeated Measures Analysis of Variance for Symptom Severity and Functional Status (N=22)

Source	df	F Symptom Severity	 Functional Status
		Within subjects	
Between measures (time)	3	19.03**	7.02*
Within measures (error)	63	(.25)	(.24)

Note. Values enclosed in parentheses represent mean square errors.

*p = .0004. **p = .0000

Table 7

Mean Score Differences Before and After Splinting (N = 22)

Comparison	Symptom Severity	Functional Status
1-2 weeks before vs. immediately before	.10	.06
Immediately before vs. 2 weeks after	.59[a]	.31
Immediately before vs. 10-12 weeks after	.86[a]	.53[a]

[a]Mean score differences are significant at $\alpha = .05$ in the post hoc Tukey's HSD Test, where Tukey's HSD for symptom severity = .40, Tukey's HSD for functional status = .39

Characteristics of Improved and Not Improved Groups

Tables 8 and 9 present a comparison of characteristics between groups with improved, deteriorated, and unchanged symptom severity and functional status three months after splinting.

Improved Symptom Severity and Functional Status

Most participants had decreased symptom severity (n = 17) and improved functional status three months after splinting (n = 16). No specific trend was observed in gender, hand(s) splinted, and history of other treatments for CTS. The three participants in a younger age range of 18 to 25 showed significant decreases in symptom severity, though older individuals aged 66 to 73 years (n = 2) also responded fairly well to splinting. Participants with duration of symptoms up to 104 weeks responded well to splinting. Those with shorter duration of symptoms either had improved or deteriorated symptoms and function. For other medical conditions, participants who had tendinitis (n = 3) all had improved symptoms and function three months after splinting.

Deteriorated Symptom Severity and Functional Status

For participants with deteriorated symptom severity (n = 4) and deteriorated functional status (n = 2), the following characteristics were observed. Participants with duration of symptoms of 260 weeks (n = 2) showed an increase in symptom severity, though their functional status improved. Participants with deteriorated symptom severity (n = 4) and deteriorated functional status (n = 2) were employed in clerical occupations or sales and service occupations. Those who had a significant increase in symptom severity (n = 2) had other medical conditions of rheumatoid arthritis, and multiple conditions of

diabetes, neuropathy, angina, and anxiety. Two participants with non-significant deterioration in symptom severity or functional status worked 12 to 14 hours per day with their hands. One participant who had an increased symptom severity was known to be non-compliant with splint wear.

Unchanged Symptom Severity and Functional Status

The unchanged symptom severity (n = 1) and functional status (n = 3) of three participants were due to a ceiling effect (mean score = 1 at each of the measurement time). One participant who was in an advance stage of CTS scored 1 on the symptom severity and functional status scales. Two participants who had mild CTS also scored 1 on the functional status scale. One participant had deteriorated functional status at 2 weeks after splinting but improved to the pre-splinting functional status at 10 to 12 weeks.

Table 8

Characteristics of Participants with Improved/Not Improved Symptom Severity Three Months after Splinting (N = 22)

Characteristics	Number		
	Improved SS n=17 (2)	Deteriorated SS n = 4 (2)	Unchanged SS n = 1
Gender			
Female	11 (1)	3 (1)	0
Male	6 (1)	1 (1)	1
Hand(s) Splinted			
Right	9 (1)	0	1
Left	3 (1)	2 (1)	0
Bilateral	5	2 (1)	0
Age			
18 - 25	3	0	0
26 - 35	0	1 (1)	0
36 - 45	6	1	0
46 - 55	6 (2)	1	0
56 - 65	1	1 (1)	0
66 - 73	1	0	1

Note. SS = Symptom Severity. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant.

Table 8 (Cont'd)

Characteristics of Participants with Improved/Not Improved Symptom Severity Three Months after Splinting (N = 22)

Characteristics	Number Improved SS n=17 (2)	Deteriorated SS n = 4 (2)	Unchanged SS n = 1
Duration of Symptoms (weeks)			
1 - 13	9 (1)	2 (1)	0
14 - 26	5 (1)	0	0
27 - 39	1	0	1
40 - 52	1	0	0
104	1	0	0
260	0	2 (1)	0
Occupation			
Clerical	7 (1)	2	0
Graphic Arts	1	0	0
Sales & Service	5 (1)	2 (2)	1
Trde, Trnspt & Equipmt. Optrs.	3	0	0
Electronics Assemblers	1	0	0

Note. SS = Symptom Severity. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant. Trde, Trnspt & Equipmt. Optrs = Trade, Transport & Equipment Operators.

Table 8 (Cont'd)

Characteristics of Participants with Improved/Not Improved Symptom Severity Three Months after Splinting (N = 22)

Characteristics	Number		
	Improved SS n=17 (2)	Deteriorated SS n = 4 (2)	Unchanged SS n = 1
Other Medical Conditions			
Tendinitis	3 (1)	0	0
Rheumatoid Arthritis	0	1	0
Diabetes & Fibromyalgia	1	0	0
Diabetes, Neuropathy, Angina & Anxiety	0	1	0
Epilepsy, Colitis & Asthma	1	0	0
Plantar Fasciitis	0	1 (1)	0
Other (Colitis, Cancer, Eczema)	3	0	0
History of Other Treatments for CTS			
Anti-inflammatory	0	1 (1)	0
Anti-inflammatory & Physiotherapy	2 (1)	0	0
Anti-inflammatory & Analgesics	0	1	0
Analgesics	4	0	0
Cortisone injection	0	1	0
Cortisone injection & Analgesics	1	0	0
Tensor bandage	1	0	0

Note. SS = Symptom Severity. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant. Some participants do not have other medical conditions or history of other treatments for CTS.

Table 9

Characteristics of Participants with Improved/Not Improved Functional Status Three-months after Splinting (N=22)

Characteristics	Number Improved FS n = 16 (8)	 Deteriorated FS n = 2 (2)	 Unchanged FS n = 4
Gender			
Female	11 (5)	(2)	2
Male	5 (3)	(0)	2
Hand(s) Splinted			
Right	7 (4)	(1)	2
Left	3 (2)	(0)	2
Bilateral	6 (2)	(1)	0
Age			
18 - 25	2 (1)	(1)	0
26 - 35	1 (1)	(0)	0
36 - 45	5 (3)	(0)	2
46 - 55	6 (2)	(1)	0
56 - 65	1 (1)	(0)	1
66 - 73	1	(0)	1

Note. FS = Functional Status. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant.

Table 9 (Cont'd)

Characteristics of Participants with Improved/Not Improved Functional Status Three Months after Splinting (N = 22)

Characteristics	Number Improved FS n = 16 (8)	Deteriorated FS n = 2 (2)	Unchanged FS n = 4
Duration of Symptoms (weeks)			
1 - 13	7 (4)	(2)	2
14 - 26	5 (2)	(0)	0
27 - 39	0	(0)	2
40 - 52	1 (1)	(0)	0
104	1	(0)	0
260	2 (1)	(0)	0
Occupation			
Clerical	6 (2)	(1)	2
Graphic Arts	1	(0)	0
Sales & Service	6 (4)	(1)	1
Trde, Trnspt & Equipmt. Optrs.	2 (1)	(0)	1
Electronics Assemblers	1 (1)	(0)	0

Note. FS = Functional Status. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant. Trde, Trnspt & Equipmt. Optrs = Trade, Transport & Equipment Operators.

Table 9 (Cont'd)

Characteristics of Participants with Improved/Not Improved Functional Status Three Months after Splinting (N = 22)

Characteristics	Number Improved FS n = 16 (8)	Deteriorated FS n = 2 (2)	Unchanged FS n = 4
Other Medical Conditions			
Tendinitis	3 (2)	(0)	0
Rheumatoid Arthritis	1	(0)	0
Diabetes & Fibromyalgia	1	(0)	0
Diabetes with Neuropathy, Angina, Anxiety	0	(1)	0
Epilepsy, Colitis, Asthma	1	(0)	0
Plantar Fasciitis	1 (1)	(0)	0
Other (Colitis, Cancer, Eczema)	3	(0)	0
History of Other Treatments for CTS			
Anti-inflammatory	1 (1)	(0)	0
Anti-inflammatory & Physiotherapy	2 (1)	(0)	0
Anti-inflammatory & Analgesics	1	(0)	0
Analgesics	3	(0)	1
Cortisone injection	0	(1)	0
Cortisone injection & Analgesics	1	(0)	0
Tensor bandage	0	(1)	0

Note. FS = Functional Status. Number in ( ) = Number out of n participants whose improvement or deterioration is not statistically significant. Some participants do not have other medical conditions or history of other treatments for CTS.

Phalen's Test and Tinel Test

Phalen's test and Tinel test were performed on all participants before and after splinting. All participants had positive Phalen's test or Tinel test, or both, before splinting. Those with negative Phalen's test and Tinel test three months after splinting all had significantly improved or same symptom severity and functional status.

Grip Strength

Power grip strength was tested in 18 participants before splinting, 2 weeks, and 10 to 12 weeks after splinting. The data collected was incomplete because obtaining grip strength was not originally part of the study, but the data was included to provide objective measurement on the participants' progress. The available data on grip strength for 18 participants is presented in Appendix I. It was observed that those with significant improvement on symptoms and function had increased power grip strength 10-12 weeks after splinting. Participants with deteriorated symptoms also had decreased grip strength. However, grip strength was inconsistent with improved or deteriorated functional status.

Compliance with Splint Wear

Compliance with splint wear was defined as wearing the CTS splint at night at least 80% of the time in a two-week period, and occasionally during the day. If symptoms persist, the participants should continue to wear night splint until there is improvement. From the collected record cards and verbal reports from the participants, most participants wore the splint at night and occasionally during the day. Some participants weaned off wearing splint when symptoms subsided, while other participants still wore the splint. Non-compliant participants (n=2) had deteriorated conditions of carpal tunnel syndrome.

Changes in the Nature of Work

Out of the 15 participants who had significant decrease in symptom severity after splinting, seven (47%) reported positive changes in the nature of their work. Five out of eight participants (62.5%) with significant improvement in functional status reported positive changes in the nature of their work.

Examples of the positive changes in the work nature are as follows. Participants used ergo/wave keyboard (n = 2), used wrist support on mouse pad (n = 3), took more breaks when an ache began (n = 1), spent shorter time typing (n = 2), changed the height of their chair (n = 2), work station modified according to advice from Workers' Compensation Board (n = 1), exercised their arms, wrists, and hands (n = 2), positioned their wrists in neutral while using hands (n = 1), used a new machine at work instead of using hands (n = 1), less physical work (n = 1), or stopped working (n = 1).

Some participants with increased symptom severity (n = 1) and deteriorated functional status (n = 1) had reported negative changes in the nature of their work. These included going back to work in the same environment 12 to 14 hours per day after taking sick leave (n = 1), and changed job but continuing to work using repetitive hand motions for long hours (n = 1).

Activities that Aggravate the Symptoms

Activities that were reported to aggravate symptoms include the following: housework, e.g. vacuuming, peeling with peeler, chopping, washing dishes (n = 8), positioning of wrist while sleeping (n = 6), holding with hand in one position for an extended period of time, e.g. using screwdrivers, using hammer, holding a book, holding

telephone (n = 6), using computer (n = 5), writing (n = 5), driving (n = 5), lifting (n = 4), gardening (n = 3), and blow drying hair (n = 2).

Participants' Comments

Some participants gave positive comments about splinting: "The splints have worked amazingly well"; "Overall splints have made a fantastic change"; "The brace has eliminated the loss of feeling in my hand". Other comments included: "If idle or splinted they (my wrists) seize up"; "When I leave the brace off, after about one night the tingling returns"; "I have not been wearing the brace during the day as it is not compatible to typing or doing housework".

Summary of the Results

Fifteen participants (68%) showed significant decrease in symptom severity while 8 (36%) showed significant improvement in functional status three months after splinting. Most participants were middle-aged females engaged in occupations that presented high risks for CTS. Comorbid conditions (such as diabetes) and other treatments for CTS (such as anti-inflammatory) were recorded. Characteristics of improved and not improved groups were compared. A relatively shorter duration of symptoms seemed to be associated with success in splinting. The results also suggested that a relatively longer duration of symptoms, other medical conditions, unchanged work environment, and non-compliance with splint wear were factors associated with failure in splinting. Observations from the Phalen's test and Tinel test, grip strength test, the splint wearing schedule record cards, and the open ended questions from the questionnaires were reported.

CHAPTER 5

DISCUSSION

The primary finding of the research was that clients with work-related carpal tunnel syndrome experienced significant decrease in symptom severity and significant improvement in functional status three months after splinting. Two weeks after splinting, clients had significant decrease in symptom severity but not significant increase in functional status. Therefore, the two null hypotheses were rejected.

This study is unique in that it is the first research on work-related CTS and splinting, and the findings are positive.

Demographic Characteristics

As expected, there were more women (64%) than men in the study and most participants (64%) were middle-aged from 36 to 55 years. This is consistent with the gender and age distribution in the CTS literature (de Krom et al., 1992; Katz, 1994, Kruger et al., 1991). More than 32% of the participants had bilateral involvement. This is also in agreement with findings from previous studies (Banta, 1994; Burke et al., 1994; Courts, 1995; Dolhanty, 1986; Kaplan et al., 1990; Kruger et al., 1991; Stanek & Pransky, 1996; Weiss et al., 1994). Participants all engaged in occupations that present risks for CTS e.g. computer operators, typists, assembly workers, and construction workers, as suggested in the literature (Alberta Occupational Health and Safety, 1993; Greer et al., 1992).

Symptom Severity and Functional Status

The results indicated the degree of symptom relief and functional improvement of the participants. On average, there was a decrease of .86 in symptom severity and an improvement of .53 in functional status three months after splinting, using a 5-point scale. The small numbers of .86 and .53 are probably associated with the fact that a majority of the participants only had mild symptoms and mild functional deficits before splinting.

Three months after splinting, most participants (n = 16) had mild symptoms and functional deficits (range = 1-2, mean score = 1.33), while they had various degree of symptom severity and functional deficits (range = 1-3.73, mean score = 2.16) before splinting. One participant had no symptom and no functional deficit before and after splinting. However, nerve condition test confirmed that he had CTS. The details for this participant are discussed in a later section "Treatment for CTS". Two participants had total symptom relief two weeks after splinting and remained symptom-free at three months; their functional status was not affected by CTS, and neither had other medical conditions. This showed that they were at an early mild stage of worked-related CTS, and responded very well to a conservative treatment like splinting. This outcome concurs with the literature (Johnson, 1995; Kruger et al., 1991; Stahl & Yarnitsky, 1996). Another two participants with no other medical conditions had their hand function improved to normal, and had very mild symptoms three months after splinting. These participants were also at a mild stage of CTS, which responded well to splinting. The number of participants with total symptom relief was less than the findings (13% to 67%) from the literature (Banta, 1994; Kruger et al., 1991; Weiss et al., 1994). This may be

related to the methodology of data collection and confounding factors such as other treatments for CTS in this study.

Overall, functional status was not significantly improved in 2 weeks but significantly improved at 3 months after splinting. Five participants (23%) of age 41 to 73 (mean age = 56.1 years) had deteriorated function in 2 weeks and improved function at 3 months. It is observed that compared to the symptom severity, it may take longer (more than 2 weeks) for the functional status of an older age group to respond to treatment like splinting.

Recurrence of CTS symptoms and functional deficits were only found in two (9%) and one (5%) participant respectively, who improved in 2 weeks but deteriorated at 3 months after splinting. The results are far better than the recurrence rate of 34% to 90% from the literature (Weiss et al., 1994).

Predictive Factors in the Treatment of CTS

No participant in the study had more than two factors that predict failure of conservative therapy. This is not in agreement to the literature (Kaplan et al., 1990; Stahl & Yarnitsky, 1996).

Three participants had deteriorated symptoms, one had deteriorated function, while one had deteriorated symptoms and function three months after splinting. It was observed that symptom duration of 5 years with other inflammatory conditions (rheumatoid arthritis and plantar fasciitis) appeared to be two factors that associate with failures in symptom relief by splinting (n = 2). Participants with symptom onset of 1 year (n = 1) and 2 years (n = 1) had improved symptoms and function three months after splinting. For those who had symptom onset of within three months (n = 11), two of

them (18%) had deteriorated symptoms and function after treatment. These findings do not concur with the literature which suggests symptom onset over 10 months as a factor to predict failure of splinting (Kaplan et al., 1990), and that splinting being most effective if applied within three months of symptom onset (Kruger et al., 1991). In this study, most (82%) of the participants with three months symptom onset had improved symptoms and function after splinting. Obviously, the longer the duration of symptoms, the less responsive is CTS to treatment. However, the cut off point needs to be further investigated with other factors taken into consideration.

Contrary to the literature, age over 50 or 55 years was not a factor in predicting failure in this study. Only one participant with deteriorated symptoms was of age over 55. Age range was scattered for participants with improved or deteriorated symptoms and function.

Other than the factors mentioned above, other medical conditions, nature of work and work conditions, and compliance with splint wear all appeared to be factors associated with failure of treatment, as observed from the results of this study.

Changes in the Nature of Work

From the participants' report, 47% with improved symptoms and 63% with improved function had some positive changes in the nature of their work. This suggested that ergonomic modification of the work environment was important in the rehabilitation of CTS.

Limitations

A limitation of the study is that for ethical reasons, we could not withhold splinting or other treatments such as anti-inflammatory medications from the participants with CTS. Therefore, we did not have a control group, and we are not sure whether the improvement is solely due to splinting.

Because of time constraints, a convenient sample from one hospital was used. This sample may not be representative of all work-related CTS. For example, the occupation and age range may be different for clients living in different areas. However, this kind of sampling is commonly used in other similar clinical studies. If generalizations are to be made to other populations, the closest generalization would be to people living in Canada with a similar diagnosis of work-related CTS.

Long term follow-up was set at three months due to time constraints and limited funding. The small sample size and the subjective measurement using a self-administered questionnaire may be viewed as limitations. However, the positive findings from a small sample can also be viewed as a strength of this study. Although a subjective measure, the CTS questionnaire has been shown to be reliable and valid. It has been used in several recent studies in 1997 and 1998, and has been found to be highly comparable to generic measures like the SF-36 (Bessette et al., 1998; Pransky et al., 1998). Data from objective tests like the power grip strength test may be used to further validate the CTS questionnaire, provided we administer the grip strength test in a way that does not aggravate the inflammatory condition of CTS.

Work-related CTS

In this study, all participants reported that they have "work-related" CTS. According to Louis et al. (1996), a work-related disease is not the same as an occupational disease, which is a disease caused solely by one's occupation. Work-related diseases are defined as multifactorial when the work environment and the performance of work contribute significantly, but as one of a number of factors, to the causation of diseases. Given this definition, we should take into consideration other non-occupational factors that may cause CTS. It was found that some participants in this study have other medical conditions such as rheumatoid arthritis and diabetes, while others engaged in hobbies or household activities that required repetitive or forceful wrist movements. All these might be causal factors for CTS other than work. As argued by Louis et al. (1996), a factor may be considered causal if its presence, among other causal factors, increases the rate of disease compared with its absence, when all other confounding factors and systemic errors are controlled properly. Hence, a control group, which was not employed in this study, would be useful to further validate that work is the major casual factor for CTS. A comprehensive history-taking procedure is deemed essential for controlling the confounding factors and systemic errors.

Treatment for CTS

Eleven participants (50%) in this study used other conservative treatments (such as anti-inflammatory medications) for CTS in addition to splinting. No specific trend could be identified to suggest whether other conservative treatments made a difference or not. This might be related to the small sample size compared to the variety of conservative treatments employed.

One drop-out participant went for surgery one month after the initial application of CTS splint. The data collected two weeks after splinting showed a significant deterioration in symptom severity and functional status. Upon closer examination of the data collected, this 27-year-old woman with 24-week history of CTS symptoms had to work long hours (12 hours) every day and required prolonged forceful gripping of her affected hand at work. Compliance with splint wear was uncertain as she dropped out from the first follow-up appointment. The data for two weeks post-splinting was collected by mail. Thus, several factors might have been affected the progress of the syndrome.

Wilson and Sumner (1995) suggest classification of patients with CTS into four categories to decide for treatment. Patients who (1) developed CTS as a reversible disorder, and should be treated conservatively; (2) are symptomatic, but do not have electrodiagnostic evidence of CTS. They are in the first stage of CTS and are likely to improve with conservative treatment; (3) are at the second or third stages of CTS with symptoms and electrodiagnostic evidence of CTS. Conservative treatment may offer symptomatic relief but surgery should be the ultimate choice; (4) are asymptomatic but have electrodiagnostic evidence of CTS. (4i) are with advanced CTS, positive symptoms have gone, had markedly abnormal electrodiagnostic studies, and should receive surgery; (4ii) are with mildly abnormal nerve conduction studies, can be treated conservatively until they develop symptoms or electrodiagnostic studies show progression.

According to this classification, one 68 year-old men in this study who presented with no symptoms but had been diagnosed as having CTS for 30 weeks by nerve conduction test might fall into category (4ii). The nerve conduction test results was the

same three months after splinting. As there was no progression of the syndrome, treatment by splinting should be appropriate for him at this time.

Though Wilson and Sumner (1995) prefer surgery to conservative treatment for CTS, their classification still shows that conservative treatment is the treatment of choice for early mild CTS, and nerve conduction test, which is not performed for every participants in this study, should be used to provide objective information on the severity of the syndrome. Johnson (1995) argues that early conservative treatment such as splinting is desirable and can be effective if used appropriately, rather than having immediate surgery for CTS. Harter et al. (1993) find in a study with 265 patients that both surgically and non-surgically treated patients are satisfied with the results. A study in Netherlands with 92 neurologists shows that there is no consensus regarding the optimal treatment of CTS (Scholten, de Krom, Bertelsmann, & Bouter, 1997).

In summary, though there is no consensus for optimal treatment of CTS, a conservative treatment like splinting is found to be effective for early mild CTS. Those who prefer early surgery because of the quicker rehabilitation process should consider the possibility of symptom relapse after surgery, if the primary cause of CTS was not removed.

Clinical Implications

The present study provides data about the long term effects of splinting on the degree of symptom relief and improvement of function for clients with work-related CTS. There are several clinical implications from the study.

First, occupational therapists can provide evidence-based treatment for clients with work-related CTS. As splinting evidently helps to relief symptoms and improve function, treatment protocol can be provided for clients to obtain optimal results.

Second, the effectiveness of splinting may be anticipated from the other factors such as comorbid conditions and symptom duration. As other factors seem to be associated with the treatment outcome, clients with those factors can be made aware of what they should expect from splinting.

Third, the results of this study may help occupational therapists in making treatment recommendations to clients and physicians based on individual client's conditions and response to splinting.

Fourth, the study may assist in the case management of clients with work-related CTS. The CTS questionnaire is a subjective but reliable and valid instrument while the grip strength test, the Phalen's test, and the Tinel test are objective tools for outcome measures.

Fifth, the results of the study have implications on reducing CTS-related work disability. Katz et al. (1998) find from a study of 350 patients that worse upper extremity functional status and having a contested Workers' Compensation claim are critical predictors of work absence, and should be principal targets of interventions to reduce work disability in CTS. As it is evident that splinting is effective in improving upper extremity functional status, intervention by splinting can indirectly help to decrease CTS-related work disability.

Research Implications

The present study has provided preliminary data that can be used for future research. The study used three months for long term follow-up with a small sample of 22 participants; future studies could address the same research question using a longer follow-up period of at least 6 to 12 months with a larger number of clients. A randomized sample and a control group can be employed for better generalization and for increased validity of the results.

Future studies might exclude clients with other medical conditions (such as rheumatoid arthritis) because they seem unlikely to benefit from the treatment protocol of the study, e.g. the type of splint used and the splint wearing schedule. The history of clients' hobbies and non-work interests that may contribute to CTS, current and past employment, previous injury, and any former compensable illness should be included for discussion. These can be done in an initial interview with the client before performing the study.

For a deeper understanding of work-related CTS, research can be performed to relate splinting results to the type of work and amount of repetition and force needed at work. Thus, we can find out if CTS clients from a particular kind of work respond to treatment like splinting.

Conclusion

As the incidence of work-related CTS continues to increase in recent years, the direct and indirect costs from CTS claims, rehabilitation, and loss of working days have been remarkable. Although studies have been performed to determine the effectiveness of splinting for early CTS, little is known about the long term effects of splinting on the

degree of symptom relief and improvement of upper extremity functional status for clients with work-related CTS.

The present study indicates that for clients with work-related CTS, there is evidence of statistically significant improvement in the symptom severity and upper extremity functional status three months after splinting; whereas two weeks after splinting there is significant improvement in symptoms but not function. Long duration of symptoms of five years or more, other medical conditions, work conditions, and non-compliance with splint wear may be associated with failure of therapy.

The results also have important clinical implications for occupational therapists in the management of work-related CTS. Other than providing treatment like splinting when problems occur, occupational therapists can also play an important role in the prevention of work-related CTS, especially with the world-wide trend towards increasing use of computers. Occupational therapists can act as educators to educate employers and employees in the prevention of CTS in industries that present risks for CTS, e.g. Education on the use of ergonomic design in work stations for computer operators and cashiers. Future research is recommended in a larger study with a longer follow-up period, and with well-controlled confounding and predictive factors.

To conclude, splinting for three months is found to be effective in relieving symptoms and improving upper extremity functional status for clients with work-related CTS.

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APPENDIX A

SAMPLE SIZE CALCULATIONS

Sample size calculation for treatment studies: (Warren, 1992, p.74)

$$n/group = (2\sigma)^2/(\mu_2-\mu_1)^2 \times f(\alpha,\beta)$$

where n = number of participants required
μ_1 = mean symptom severity before treatment = 3.1*
μ_2 = mean symptom severity after treatment = 2.0*
σ = standard deviation for μ_1 = .9*
α = type I error
β = type II error
(α,β) = value from table for required number of participants

at an α level of .05 and a study power of .80 (β level of .2), value of (α,β) = 7.9

$$n = (2 \times .9)^2/(2.0-3.1)^2 \times 7.9$$
$$= 2.68 \times 7.9$$
$$= 21.2$$

Therefore, approximately 22 participants are needed at an α level of .05 and a study power of .80. An additional 15% (n=3) are included for potential dropout, leading to a total of 25.

* The values of μ_1, μ_2 and σ were obtained from a previous study done by Levine et al. (1993) on 67 subjects with CTS pre- and post-operatively.

Sample size table for the analysis of variance: (Cohen, 1988, p.384)

At α = .05, power = .80, k = 4, u = 3

where k = number of level of measurement
u = degree of freedom of the numerator of the F ratio = k-1

Sample size (n) = 18 for a large effect size (f) of .40
Sample size (n) = 23 for a large effect size (f) of .35

Therefore, a sample size of 22 produces a large effect size of between .35 to .40.

APPENDIX B

INTRODUCTORY LETTER

LANGLEY
MEMORIAL
HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

University of Alberta
Edmonton

Dear _____,

A study on the effectiveness of splinting for people with work-related carpal tunnel syndrome is being done at the Langley Memorial Hospital (LMH), aiming to evaluate and further improve the treatment program for carpal tunnel syndrome, as part of a Master of Science program at the University of Alberta (U of A). The researchers are: Ms. Stella Li, principal investigator, LMH and U of A; Dr. Lili Liu, Dr. Sharon Warren, and Professor M. Miyazaki, U of A. Referral records show that you are diagnosed as having carpal tunnel syndrome and will be coming for splinting at the Occupational Therapy Department of the Hospital.

Your involvement will be very important to the success of this project. We would appreciate your participation in the study by filling out questionnaires about your severity of symptoms for carpal tunnel syndrome and your functional status before and after splinting. It will take about 10 minutes to complete the questionnaire. All personal information given will be kept confidential.

The time you spend on the study will be very much appreciated. The information received will be analyzed and interpreted, and the results will be presented at conferences and published in journals. You will receive a summary of the findings. We will be calling you soon to confirm whether you are interested in participating. A consent form and a sample questionnaire is enclosed for your information. If you have any questions before we call, please contact Ms. Stella Li at the phone number listed below. Thank you for considering our request.

Yours truly,

_____

Ms. Stella Li, Occupational Therapist
Occupational Therapy Department
Langley Memorial Hospital. Phone no.: 533-6407

APPENDIX C

LANGLEY MEMORIAL HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

University of Alberta
Edmonton

CONSENT FORM

Title of Study: Effectiveness of splinting for work-related carpal tunnel syndrome: a three-month follow-up study

Investigators: Ms. Stella Li, Occupational Therapist, LMH. (604) 533-6407
Dr. Lili Liu, Assistant Professor, University of Alberta. (403) 492-5108
Professor M. Miyazaki, Associate Professor & Acting Chair of the Department of Occupational Therapy, University of Alberta. (403) 492-9127
Dr. Sharon Warren, Professor, University of Alberta. (403) 492-7856

Purpose: To determine if wearing a splint will reduce symptoms (such as pain and numbness) and improve functional status (such as the ability to perform household chores) for people with work-related carpal tunnel syndrome. The project is part of a Master of Science program at the University of Alberta. You will be asked to fill out questionnaires which takes about 10 minutes each time, about symptom severity over your affected hand, and your functional status. You will need to self-rate the questionnaires 2 times (1-2 weeks and immediately) before splinting and 2 times (2 weeks and 10-12 weeks) after splinting in the Occupational Therapy Department at the Langley Memorial Hospital.

Consent:

I, _____, agree to participate in the above named project.

I understand that my participation in this project is voluntary. I may withdraw from the study at any time without consequences.

I also understand that all personal information given will be treated confidentially. My name will not appear on any of the completed questionnaires (only an identifying code number), nor will it be associated with any publications arising from the research.

All questions that I had about the project have been answered to my satisfaction, but I will be free to ask further questions of any investigators at any time at the above listed phone numbers.

_____	_____	_____
Participant	Signature	Date
_____	_____	_____
Witness	Signature	Date
_____	_____	_____
Principal Investigator	Signature	Date

APPENDIX D

EDINBURGH HANDEDNESS INVENTORY by Oldfield, 1971

Instructions: "I am going to read a list of activities to you. I would like you to tell me whether you prefer to do this activity with your left hand only, your right hand only or either hand."

	LEFT	RIGHT
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		

APPENDIX E

LANGLEY MEMORIAL HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

University of Alberta
Edmonton

SPLINTING INFORMATION - CARPAL TUNNEL SYNDROME

This carpal tunnel syndrome splint was made for _____ by your occupational therapist _____ upon referral by Dr. _____.

What is Carpal Tunnel Syndrome (CTS)?
Carpal tunnel syndrome is a common condition affecting the hand and the wrist. The median nerve (the major nerve of the hand) that runs through the carpal (meaning wrist) tunnel is compressed, resulting in pain, clumsiness of the hand, and numbness or tingling in the thumb, index, middle, and ring fingers. Symptoms are often most noticeable during sleeping hours. Activities that involve repetitive motion or exertion of the wrist in extreme wrist positions increase the risk for CTS.

Purpose of splinting:
The purpose of splinting is to minimize compression to the median nerve and maximize the available carpal tunnel space, by immobilizing the wrist in a neutral position (keeping the wrist straight), so as to relieve symptoms and improve functional status.

When to wear your splint:
You should wear your splint

- **at night**; and,
- during the day if you are performing activities that involve repetitive or extreme wrist movements.

*You are given a wearing record card. Please **record your weekly wearing schedule** for future evaluation, and bring the record card back for your next therapy appointment.

During the day, you should remove the splint at least twice for wrist and finger exercises (flexion, extension, deviations) as demonstrated, to prevent stiffness.

How to care for your splint:
The splint should be cleaned with lukewarm water and mild detergent only.
You should avoid leaving the splint under any heat or hot environments, else the splint will be destroyed.
If there is any discomfort or if adjustment of the splint is required, please consult your occupational therapist immediately.

Next Appointment:
Your next appointment with your occupational therapist will be on _____ .
If you have any questions or problems with CTS splinting, please contact your occupational therapist _____ at 533-6407 from 8am to 4pm Mon.- Fri., or leave a message any time.

APPENDIX F

SPLINT WEARING SCHEDULE RECORD CARD
(for participants to carry in a wallet or purse)

Front:

Week of _____ to _____

day→ ↓time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
am							
pm							
night							

Back:

Name: _____
Code: _____

Record your splint wearing schedule by putting the no. of hours in the am, pm, and night section.

Bring this card back for your next therapy appointment.

APPENDIX G

LANGLEY MEMORIAL HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

University of Alberta
Edmonton

Carpal Tunnel Syndrome Questionnaire

Name: _____
Date:_____ Code: _____

Part I: Background Information

(1st questionnaire)

Gender: _____(M/F)

Date of Birth: _____(dd/mm/yy)

Duration of symptoms before splinting: _____weeks

Other medical conditions/disease: _____

Other treatments for carpal tunnel syndrome:
(please indicate date started and frequency)

Medications/Injections: _____

Others: _____

Occupation: _____
Description of nature of work (with regard to use of hands):
(e.g. data entry 6hrs/day, grocery checking 4 hrs/day)

_____

_____

Activities that aggravate your symptoms (e.g. the activity aggravates numbness and pain of the affected hand): _____

_____

Remarks: _____

LANGLEY
MEMORIAL
HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

University of Alberta
Edmonton

Carpal Tunnel Syndrome Questionnaire

Name: _____

Date: _____ Code: _____

Part I: Background Information

(2nd to 4th questionnaire)

Other medical conditions/disease: _____

Other treatments for carpal tunnel syndrome:
(please indicate date started and frequency)

Medications/Injections: _____

Others: _____

If you filled out this questionnaire before, please indicate any changes in your nature of work, the equipment or tools you use (e.g. use of wrist pads), or the way of performing tasks using your hands (e.g. rest the wrists on wrist pads while typing).

_____

_____

Remarks: _____

Part II: Symptom Severity Scale

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The following questions refer to your symptoms for a typical twenty-four-hour period during the past two weeks (circle one answer to each question).

---

1. How severe is the hand or wrist pain that you have at night?
   1 I do not have hand or wrist pain at night.
   2 Mild pain
   3 Moderate pain
   4 Severe pain
   5 Very severe pain

2. How often did hand or wrist pain wake you up during a typical night in the past two weeks?
   1 Never
   2 Once
   3 Two or three times
   4 Four or five times
   5 More than five times

3. Do you typically have pain in your hand or wrist during the daytime?
   1 I never have pain during the day.
   2 I have mild pain during the day.
   3 I have moderate pain during the day.
   4 I have severe pain during the day.
   5 I have very severe pain during the day.

4. How often do you have hand or wrist pain during the daytime?
   1 Never
   2 Once or twice a day
   3 Three to five times a day
   4 More than five times a day
   5 The pain is constant

5. How long, on average, does an episode of pain last during the daytime?
   1 I never get pain during the day.
   2 Less than 10 minutes
   3 10 to 60 minutes
   4 Greater than 60 minutes
   5 The pain is constant throughout the day.

6. Do you have numbness (loss of sensation) in your hand?
   1 No
   2 I have mild numbness.
   3 I have moderate numbness.
   4 I have severe numbness.
   5 I have very severe numbness.

7. Do you have weakness in your hand or wrist?
   1 No weakness
   2 Mild weakness
   3 Moderate weakness
   4 Severe weakness
   5 Very severe weakness

8. Do you have tingling sensations in your hand?
   1 No tingling
   2 Mild tingling
   3 Moderate tingling
   4 Severe tingling
   5 Very severe tingling

9. How severe is numbness (loss of sensation) or tingling at night?
   1 I have no numbness or tingling at night.
   2 Mild
   3 Moderate
   4 Severe
   5 Very severe

10. How often did hand numbness or tingling wake you up during a typical night during the past two weeks?
   1 Never
   2 Once
   3 Two or three times
   4 Four or five times
   5 More than five times

11. Do you have difficulty with the grasping and use of small objects such as keys or pens?
   1 No difficulty
   2 Mild difficulty
   3 Moderate difficulty
   4 Severe difficulty
   5 Very severe difficulty

Part III: Functional Status Scale

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On a typical day during the past two weeks have hand and wrist symptoms caused you to have any difficulty doing the activities listed below? Please circle one number that best describes your ability to do the activity.

Activity	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	Cannot Do at All Due to Hand or Wrist Symptoms
1. Writing	1	2	3	4	5
2. Buttoning of Clothes	1	2	3	4	5
3. Holding a book while reading	1	2	3	4	5
4. Gripping of a telephone handle	1	2	3	4	5
5. Opening of jars	1	2	3	4	5
6. Household chores	1	2	3	4	5
7. Carrying of grocery bags	1	2	3	4	5
8. Bathing and dressing	1	2	3	4	5

Thank you for your time.

APPENDIX H

ETHICS APPROVAL LETTER

LANGLEY
MEMORIAL
HOSPITAL

22051 Fraser Highway
Langley
British Columbia
Canada V3A 4H4

Telephone (604) 534-4121
Fax (604) 533-6411

August 8, 1997

Ms. Stella Li
Occupational therapist
Langley Memorial Hospital
Graduate Student, MSc (OT) Program, University of Alberta
3579 East 26 Avenue
Vancouver, BC
V5R 1M5 fax 438-2470

Dear Ms. Li:

This letter confirms our previous e-mail conversations. The Ethics Committee of the Langley Memorial Hospital has approved your research study: "Effectiveness of Splinting for Work-Related Carpal Tunnel Syndrome: A Three - Month Follow Up Study."

Good luck with your studies.

Yours truly;

Dr. Lee Titterington, Ed.D.
Chair - Ethics Committee

APPENDIX I

Power Grip Strength (lb)

N=18

Code	Hand Splinted	Pre2	Post1 (2weeks)	Post2 (10-12weeks)	Symptom Severity	Functional Status
1002	R	68.0	66.0	--	NS+	NS+
1006	L	88.0	85.3	--	S+	No Change
1007	L	41.3	37.7	56.0	S+	S+
1008	R	65.5	79.6	--	S+	S+
	L	72.0	83.3	--		
1009	R	45.3	39.0	47.3	S+	NS-
1010	R	107.7	100.3	99.0	S+	NS+
1011	R	47.0	48.7	--	S+	S+
1012	R	39.7	59.7	47.3	S+	S+
	L	44.3	58.3	55.0		
1013	L	10.0	10.0	--	S-	S+
1015	R	64.7	68.3	79.3	S+	NS+
	L	70.0	73.7	78.3		
1016	L	34.0	41.7	23.7	NS-	NS+
1017	R	30.7	38.3	41.7	S+	NS+
1018	L	30.0	36.3	38.3	S+	No Change
1020	R	51.0	63.3	84.3	S+	S+
1022	R	47.3	46.7	54.0	S+	S+
1023	L	48.4	--	53.3	NS+	NS+
1024	R	76.0	79.0	78.7	No Change	No Change
1025	R	45.0	42.0	39.3	S-	NS-
	L	40.0	37.3	35.7		

Note. Pre2 = immediately before splinting. Post1 = 2 weeks after splinting. Post2 = 10-12 weeks after splinting. R = Right. L = Left. S+ = Significant improvement, NS+ = Non-significant improvement, S- = Significant deterioration, NS- = Non-significant deterioration 10-12 weeks after splinting.